

# MONTHLY WEATHER REVIEW

Editor, JAMES E. CASKEY, JR.

Volume 80  
Number 3

MARCH 1952

Closed May 15, 1952  
Issued June 15, 1952

## HAIL DAMAGE IN IOWA, 1923-1948

C. E. LAMOUREUX

Weather Bureau Office, Des Moines, Iowa  
[Manuscript received June 5, 1951]

### ABSTRACT

A distinction is made between hail as a meteorological phenomenon and hail as an economic phenomenon. A method of collecting hail damage statistics is described, and the statistics are subjected to adjustment to a common dollar base. Since there are marked differences in the use of land and in the size of counties and crop reporting districts, the data are reduced to show the dollar damage for each 1,000 acres of cropland. The resulting data are comparable, area for area and year for year. Variations in the dollar damage are shown for the different sections of the State and for the years of record. An enveloping curve is developed which shows the maximum damage for each 1,000 acres of cropland for units of area varying in size from a single township to the State as a whole. It is noted that the adjusted dollar data on damage per 1,000 acres do not reflect meteorological factors alone, but include production factors as well. A further adjustment is made, using a crop production index developed by the Iowa Department of Agriculture. The resulting damage data, as influenced by meteorological factors alone, shows less variation between the various sections of the State.

### CONTENTS

	Page
Abstract.....	37
Introduction.....	37
Hail as a climatological phenomenon.....	37
Hail as an economic phenomenon.....	38
Collection and adjustment of hail data.....	38
Distribution of hail damage.....	38
Adjustment of hail data to land productivity.....	42
Notes on individual hailstorms in Iowa.....	43
Acknowledgments.....	44
References.....	44

### INTRODUCTION

Widespread interest in hail naturally falls into two fields: first, hail as a natural phenomenon; and second, hail as an economic phenomenon. The processes by which hail is formed have been examined in many meteorological papers. The distribution of hail as a climatological phenomenon has also been the subject of many papers; it will be mentioned here only briefly to show the variation in the occurrence of hail across the State of Iowa. This paper will treat hail as an economic phenomenon, and

will consist principally of an analysis of hail damage data collected in Iowa for the 26-year period 1923-48.

### HAIL AS A CLIMATOLOGICAL PHENOMENON

Shands [1] compiled hail data for 219 first-order Weather Bureau stations in the United States for the period 1904-43. It was shown that hail frequency in Iowa averaged between two and four occurrences annually at the points for which the data were compiled. This frequency may be compared to a frequency of four to six annually over a large portion of the central Rocky Mountains with a maximum frequency of 9.5 at Cheyenne, Wyo. The frequencies for Iowa stations are given below:

Station	Years of record	Average annual frequency	Maximum annual frequency
Charles City.....	39	2.4	8
Davenport.....	40	2.6	8
Des Moines.....	40	3.4	9
Dubuque.....	40	2.8	8
Keokuk.....	38	2.8	7
Omaha, Nebr.....	40	4.0	8
Sioux City.....	40	2.9	6

The above data are for "point" observations. In the case of hail, the "point" of observation is used rather loosely, and usually includes the metropolitan area for which the observer has immediate knowledge. In any case, the area covered is seldom more than a few square miles in extent. Since hailstorms cover a small area, normally about 20 square miles, the number that may be observed at a single point is relatively small. Shands has also computed the average yearly number of days with hailstorms, 57.9, that occur in the State of Iowa, an area of 56,000 square miles, for a 25-year period, 1916-40. These latter data are taken from the records of 120 co-operative observers in the State, or roughly one observer to every 500 square miles. It is very unlikely that all hailstorms were reported from so sparse a network.

Hydrometeorological Report No. 5 [1] also gives the monthly frequency of hailstorms in Iowa. The data are reproduced in figure 1. The greatest frequency is in the month of June, with an average more than 10. The adjacent months, May and July, each have nine or more hailstorms annually; the 3 months, May, June, and July, account for almost half of the annual occurrences. This period includes the planting and early stages of the corn crop, and also the early stages of the soybean crop. While hail may occur in any month of the year, 85 percent of all occurrences have been reported in the growing season, April through September.

#### HAIL AS AN ECONOMIC PHENOMENON

While the probability of hail striking any particular farm or any particular field of grain is small, the effects of hail upon the individual farmer or grain grower may be disastrous. As a result, the utilization of insurance to offset the possibilities of individual disaster by hail damage has become widespread in the grain growing areas of the Midwest. Flora [2] has shown that the damage by hail to the wheat crop in Kansas amounts to 4 percent of the total production in the State. Reed [3] computed the average losses in Iowa to the corn crop as 1.05 percent of the total value of the crop, with a variation from 0.50 to 2.13 percent in individual years.

#### COLLECTION AND ADJUSTMENT OF HAIL DATA

It has been shown that statistics on the frequency of hailstorms taken from sparse networks are not wholly inclusive. The same statement may be made in regard to statistics of hail losses. In recent years, the Crop-Hail Actuarial Association has undertaken to compile complete hail statistics [4]. Prior to this and other similar recent attempts to compile hail statistics, Reed undertook to collect hail statistics in Iowa through the facilities of the Assessors' Annual Farm Census. This census was taken late in the year, with each of the 200,000 farmers in the State asked to estimate the dollar damage caused by hail on his farm during the past season. This method of collecting hail damage statistics has certain weaknesses which have been pointed out by Reed [5] and by Decker [6]. On

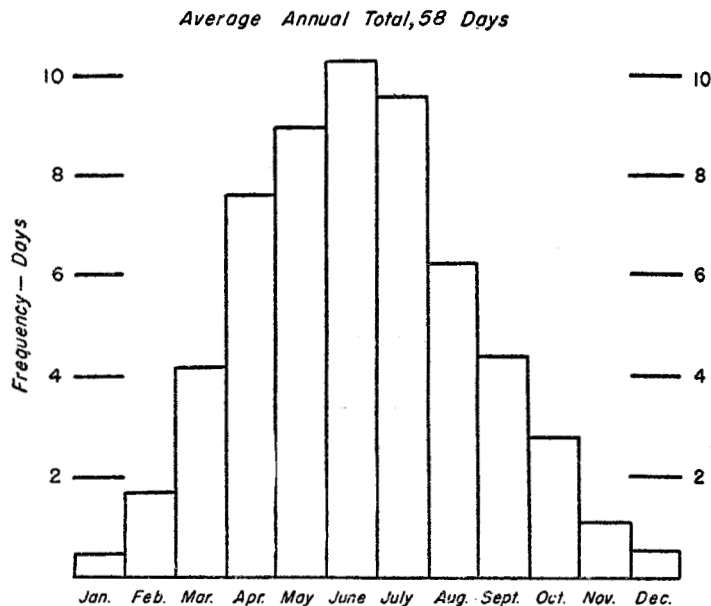


FIGURE 1.—Average monthly frequency of hail in Iowa. Based on data for the period 1916-40 (after Shands [1]).

the other hand, the question has remained the same for the period of record, and the method of collecting and tabulating the data has been consistent. Its greatest value lies in the completeness of coverage within the State's boundaries. The question was dropped from the annual census in 1949 to make space for items of more immediate importance to the farm interests.

#### DISTRIBUTION OF HAIL DAMAGE

The average hail damage per 1,000 acres cropland for each county in the State is given in table 1 and figure 2. The average for the State as a whole is 143 (dollars for each 1,000 acres of cropland). The range of the county averages is 345, from a low of 17 in Lucas County to a high of 362 in Plymouth County. From the frequency distribution of hailstorms, a ratio of hail damage of 2 : 1 may have been anticipated in the State, but the actual ratio of 20 : 1 was far greater than expected.

The arithmetical average is a poor statistic. This is shown by the average for such counties as Winneshiek in the northeast and Keokuk in the southeast, where the occurrence of a few very damaging hailstorms resulted in high averages for the period of record. The median values for each county were then computed; these are shown in table 1 and figure 3. The medial value for the State is 117 (dollars for each 1,000 acres of cropland). The range of county values is 138, from a high of 139 in Ida County in the west-central section to a low of 1 in Davis and Van Buren Counties in the southeast. The ratio between the average and median appears to be least in the northwestern counties, where hailstorms of moderate severity are not uncommon (e. g., Plymouth County, average 362, median 85), and greatest in the southeastern counties where hailstorms of even moderate intensity are

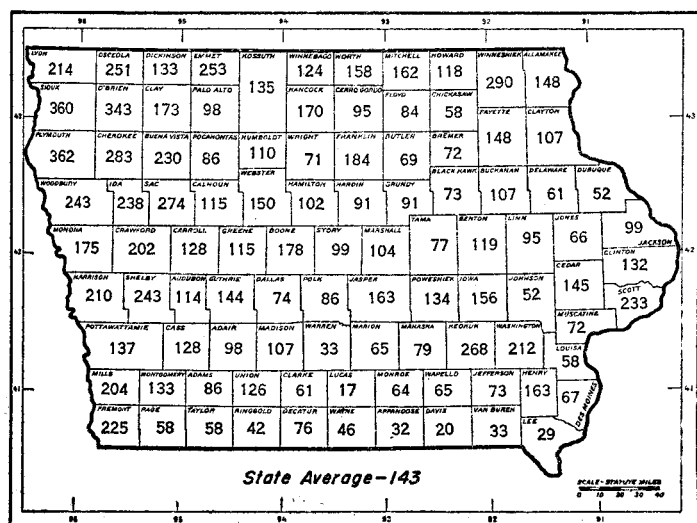


FIGURE 2.—Average annual hail damage per 1,000 acres of cropland in Iowa. Based on data for the period 1923-48 with damage adjusted to the 1909-14 price index.

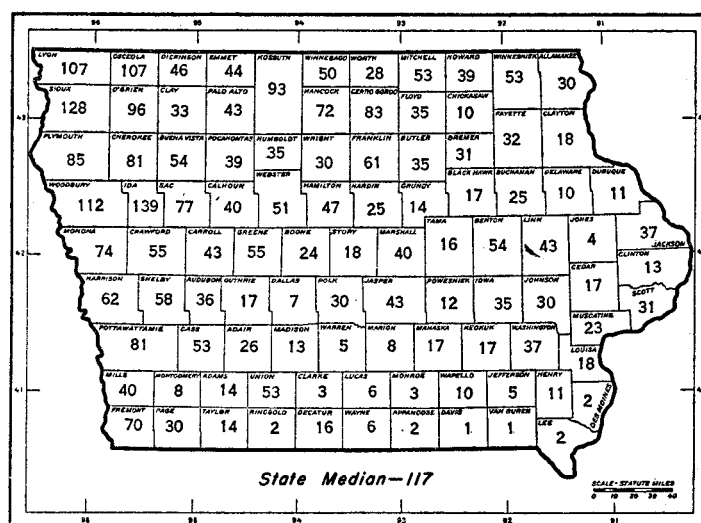


FIGURE 3.—Median annual hail damage per 1,000 acres of cropland in Iowa. Based on data for the period 1923-48 with damage adjusted to the 1909-14 price index.

relatively infrequent (e. g., Des Moines County, average 67, median 2). By reference to the median, the effect of the occasionally very severe hailstorm is minimized, as in the instances of Keokuk and Scott Counties.

Table 1 also includes data for the nine crop-reporting divisions of the State, and for selected townships in the State. The crop-reporting districts provide a convenient area intermediate in size between that of the State and the smaller county units. They also tend to group together counties having similar characteristics as to hail damage. The townships were selected to give examples of townships with excessive hail damage, those with little or no damage, and others intermediate between the two extremes.

The period during which the hail damage statistics were collected was from 1923 through 1948, a period which includes the boom years of the late twenties, the depression years of the early thirties and the war years of the early forties. Dollar values fluctuated greatly over this period, and the data for 1 year are not comparable to those of other years without adjustment. Since the major damage in Iowa is to the corn crop, it was decided to make adjustments using the annual Iowa Index of Prices Received—Grain, computed to the base period August 1909–July 1914=100. (Iowa Department of Agriculture [7]). Unless otherwise noted, all dollar data used in this study have been adjusted to that level. The process has been to convert the annual damage on the county basis to 1909–14 dollars and use the converted dollar damage in all subsequent calculations.

The price indices used are as follows:

Year	Index	Year	Index	Year	Index
1923	122	1933	54	1943	172
1924	147	1934	104	1944	190
1925	161	1935	129	1945	185
1926	114	1936	129	1946	238
1927	136	1937	161	1947	330
1928	149	1938	75	1948	329
1929	138	1939	73		
1930	122	1940	95	(1950	235)
1931	77	1941	106		
1932	44	1942	135		

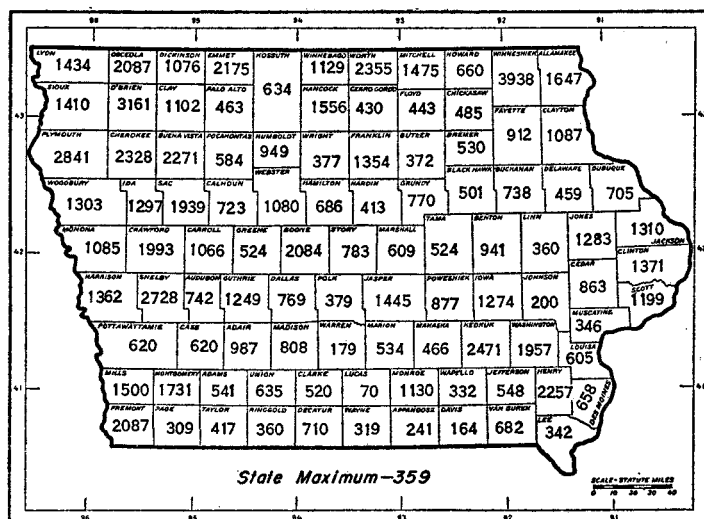


FIGURE 4.—Maximum annual hail damage per 1,000 acres of cropland in Iowa. Based on data for the period 1923-48 with damage adjusted to the 1909-14 price index.

While use of a standard price index makes it possible to compare one year with another for any given area, it is still not possible to compare one political division with another because of the wide variation in total area and in the use of that area. To meet these objections the number of 1,000-acre units of harvested cropland in each county was computed from data given by the Iowa Department of Agriculture [8]. The final data, in terms of dollar damage for each 1,000 acres of cropland and with dollars adjusted to the 1909–14 base, are directly comparable, year for year, and area for area. The data are summarized in table 1; selected statistics from the table are shown in figures 2–4.

Maximum hail damage, for each 1,000 acres of cropland, is shown in table 1 and figure 4. During the 26 years of record the maximum hail damage for individual counties varies from 70 (for each 1,000 acres of cropland) in Lucas County to 3,938 in Winneshiek County. The maximum

TABLE 1.—Summary of hail damage in Iowa for the period 1923-48

[Losses adjusted to the 1909-14 price index]

County	Total dam- age	For each 1,000 acres of cropland										
		Average annual loss	Median annual loss	Maximum and year	Frequency							
					0	1-50	51-100	101-200	201-500	501- 1, 000	1, 001- 2, 000	Over 2, 000
Adair	\$497,970	\$98	\$26	\$987-1942	0	17	3	4	1	1	0	0
Adams	297,089	86	14	541-1925	0	19	1	2	3	1	0	0
Allamakee	574,171	148	30	1,647-1944	2	15	3	1	3	1	1	0
Appanoose	106,005	32	2	241-1926	4	16	2	3	1	0	0	0
Audubon	599,880	114	36	742-1943	0	14	6	2	0	4	0	0
Benton	932,247	119	54	941-1944	1	11	6	2	5	1	0	0
Black Hawk	428,798	73	17	501-1934	1	16	4	3	1	1	0	0
Boone	1,173,175	178	24	2,084-1943	0	16	2	1	6	0	0	1
Bremer	324,453	72	31	530-1944	2	14	6	2	1	1	0	0
Buchanan	623,113	107	25	738-1931	0	16	3	2	3	2	0	0
Buena Vista	1,649,806	230	54	2,271-1933	0	13	4	4	2	1	1	1
Butler	433,384	69	35	372-1927	2	13	4	5	2	0	0	0
Calhoun	851,736	115	40	723-1943	0	14	5	3	2	2	0	0
Carroll	852,479	128	43	1,066-1943	0	15	3	1	6	0	1	0
Cass	713,200	128	53	620-1936	0	13	2	5	5	1	0	0
Cedar	857,603	145	17	863-1944	3	13	2	4	2	2	0	0
Cerro Gordo	615,943	95	83	430-1931	0	10	6	7	3	0	0	0
Cherokee	1,881,471	283	81	2,328-1943	0	10	6	1	4	4	0	1
Chickasaw	294,874	58	10	485-1933	1	16	4	4	1	0	0	0
Clarke	185,870	61	3	520-1946	7	13	2	1	2	1	0	0
Clay	1,187,753	173	33	1,102-1933	1	14	2	3	3	1	2	0
Clayton	630,317	107	18	1,087-1929	2	16	3	1	2	0	2	0
Clinton	878,453	132	13	1,371-1945	4	16	2	1	1	0	0	0
Crawford	1,546,112	202	55	1,993-1933	0	13	4	4	1	3	1	0
Dallas	471,403	74	7	769-1945	6	14	1	2	2	1	0	0
Davis	60,271	20	1	164-1931	8	15	0	3	0	0	0	0
Decatur	244,579	76	16	710-1945	5	12	3	3	2	1	0	0
Delaware	348,059	61	10	459-1944	2	17	3	1	3	0	0	0
Des Moines	216,740	67	2	658-1938	8	9	4	2	2	1	0	0
Dickinson	585,704	133	46	1,076-1943	2	12	3	4	4	0	1	0
Dubuque	260,630	52	11	705-1939	3	18	1	3	0	1	0	0
Emmet	1,217,820	253	44	2,175-1932	1	13	2	4	2	2	1	1
Fayette	1,016,065	148	32	912-1933	0	16	2	4	0	4	0	0
Floyd	477,974	84	35	443-1936	3	13	4	2	4	0	0	0
Franklin	954,902	184	61	1,354-1946	2	9	3	4	6	1	1	0
Fremont	1,071,702	225	70	2,087-1943	1	10	5	4	3	2	0	1
Greene	819,189	115	55	524-1943	0	11	5	3	5	1	0	0
Grundy	545,271	91	14	770-1927	2	16	2	4	0	2	0	0
Guthrie	791,794	144	17	1,249-1943	2	12	4	3	3	1	1	0
Hamilton	741,772	102	47	686-1932	0	14	4	3	4	1	0	0
Hancock	1,181,131	170	72	1,556-1932	0	10	6	5	3	1	1	0
Hardin	593,407	91	25	413-1927	2	15	2	2	5	0	0	0
Harrison	1,463,954	210	62	1,362-1947	0	13	2	6	1	2	2	0
Henry	603,435	163	11	2,257-1925	6	11	1	2	5	0	0	1
Howard	559,631	118	39	660-1927	0	14	4	3	3	2	0	0
Humboldt	605,541	110	35	949-1924	1	13	4	4	3	1	0	0
Ida	1,221,309	238	139	1,297-1928	2	7	3	3	7	3	1	0
Iowa	821,175	156	35	1,274-1941	3	14	1	4	1	2	1	0
Jackson	426,171	99	37	1,310-1945	2	15	3	3	2	0	1	0
Jasper	1,158,754	163	43	1,445-1943	2	11	5	2	4	1	1	0
Jefferson	257,831	73	5	548-1925	8	12	1	1	3	1	0	0
Johnson	293,627	52	30	200-1927	2	13	5	6	0	0	0	0
Jones	324,037	66	4	1,283-1933	5	17	2	1	0	0	1	0
Keokuk	1,322,260	268	17	2,471-1924	0	15	4	3	1	0	2	1
Kossuth	1,685,828	135	93	634-1946	0	9	5	7	3	2	0	0
Lee	100,061	29	2	342-1925	8	14	2	1	1	0	0	0
Linn	644,151	95	43	360-1931	0	15	1	5	5	0	0	0
Louisa	206,663	58	18	605-1938	4	14	2	5	1	0	0	0
Lucas	45,610	17	6	70-1926	5	17	4	0	0	0	0	0
Lyon	1,577,703	214	107	1,434-1943	0	9	3	8	3	1	2	0
Madison	455,311	107	13	808-1937	2	15	1	5	1	2	0	0
Mahaska	406,872	79	17	466-1943	3	13	3	4	3	0	0	0
Marion	292,529	65	8	534-1945	5	13	4	2	1	1	0	0
Marshall	649,294	104	40	609-1936	2	12	3	4	4	1	0	0
Mills	891,373	204	40	1,500-1925	3	10	3	0	8	1	1	0
Mitchell	858,071	162	53	1,475-1928	1	11	6	3	3	1	1	0
Monona	1,164,500	175	74	1,085-1925	2	8	4	5	4	2	1	0
Monroe	149,262	64	3	1,130-1926	8	12	4	1	0	0	1	0
Montgomery	568,356	133	8	1,731-1925	2	16	3	2	1	1	0	0
Muscatine	287,813	72	23	346-1941	2	15	4	1	4	0	0	0
O'Brien	2,434,040	343	96	3,161-1944	0	6	8	5	3	1	2	1
Osceola	1,298,875	251	107	2,087-1947	0	10	3	4	7	0	1	1
Page	288,939	58	30	309-1923	1	14	6	3	2	0	0	0
Palo Alto	694,913	98	43	463-1947	2	11	6	1	6	0	0	0
Plymouth	3,755,793	362	85	2,841-1932	0	8	6	3	3	3	2	1
Pocahontas	658,088	86	39	584-1933	2	13	2	7	1	1	0	0
Polk	454,780	86	30	379-1928	0	15	4	2	5	0	0	0
Pottawattamie	1,353,266	137	81	620-1947	0	12	3	2	7	2	0	0
Poweshiek	760,993	134	12	877-1923	2	16	1	0	4	3	0	0
Ringgold	157,799	42	2	360-1946	4	16	2	2	2	0	0	0
Sac	1,917,915	274	77	1,939-1933	0	7	10	3	2	1	3	0
Scott	1,036,549	233	31	1,199-1938	0	16	1	1	2	5	1	0
Shelby	1,645,593	243	58	2,728-1940	0	13	2	5	3	2	0	1
Sioux	3,503,463	369	128	1,410-1933	0	8	3	5	3	5	1	1
Story	686,172	99	18	783-1943	1	15	3	3	2	2	0	0
Tama	543,885	77	16	524-1927	3	16	1	2	3	1	0	0
Taylor	236,199	58	14	417-1927	1	16	5	2	2	0	0	0
Union	397,475	126	53	635-1938	2	11	3	6	2	2	0	0
Van Buren	93,509	33	1	682-1929	9	15	1	0	0	1	0	0
Wapello	193,932	65	10	332-1925	3	14	3	1	5	0	0	0
Warren	141,676	33	5	179-1932	2	18	2	4	0	0	0	0
Washington	1,102,368	212	37	1,957-1924	1	14	4	2	2	0	3	0
Wayne	183,820	46	6	319-1926	8	12	2	2	2	0	0	0
Webster	1,316,810	150	51	1,080-1926	0	12	4	4	4	1	1	0
Winnebago	581,837	124	50	1,129-1941	3	9	5	5	3	0	1	0

TABLE 1.—Summary of hail damage in Iowa for the period 1923-48—Continued

[Losses adjusted to the 1909-14 price index]

County	Total dam- age	For each 1,000 acres of cropland											
		Average annual loss	Median annual loss	Maximum and year	Frequency								
					0	1-50	51-100	101-200	201-500	501- 1, 000	1, 001- 2, 000	Over 2, 000	
Winnebisk.....	\$1, 790, 081	\$290	\$53	\$3, 938-1933	2	11	2	5	3	2	0	1	
Woodbury.....	2, 188, 659	243	112	1, 303-1930	0	9	3	6	3	3	2	0	
Worth.....	722, 865	158	28	2, 355-1932	1	16	4	1	3	0	0	1	
Wright.....	522, 739	71	30	377-1923	1	14	5	3	3	0	0	0	
District													
Northwest.....	20, 445, 429	242	166	813-1943	0	5	4	6	7	4	0	0	
North-Central.....	8, 640, 220	122	110	432-1932	0	8	4	11	3	0	0	0	
Northeast.....	6, 850, 162	115	69	641-1933	0	8	10	5	2	1	0	0	
West-Central.....	15, 063, 120	187	160	571-1943	0	3	4	8	10	1	0	0	
Central.....	9, 095, 716	114	94	489-1943	0	7	7	10	2	0	0	0	
East-Central.....	6, 501, 826	117	74	403-1945	0	10	6	5	5	0	0	0	
Southwest.....	5, 918, 094	127	97	518-1925	0	7	6	9	3	1	0	0	
South-Central.....	2, 359, 936	62	49	219-1945	0	13	6	6	1	0	0	0	
Southeast.....	4, 563, 942	110	42	714-1925	0	15	5	3	1	2	0	0	
State.....	79, 438, 445	143	117	359-1943	0	1	10	9	6	0	0	0	
Selected Townships													
Chequest, Van Buren Co.....	0	0	0	0.....	26	0	0	0	0	0	0	0	
Liberty, Keokuk Co.....	280, 013	798	13	16, 200-1924	11	9	1	0	2	1	0	2	
Garfield, Sioux Co.....	124, 062	276	56	3, 170-1929	5	6	7	3	3	0	0	2	
Preston, Plymouth Co.....	370, 901	792	2	15, 968-1932	11	7	2	1	1	1	2	1	
Washington, Polk Co.....	28, 080	84	0	1, 351-1941	22	2	0	0	0	1	1	0	
West Point, Lee Co.....	1, 745	8	0	209-1925	25	0	0	1	0	0	0	0	

figure for the State is 359, which occurred in 1943. The maximum values represent the extreme in a State population of 26, in a district population of 234, in a county population of 2,501, and in a township population of 41,600. In figure 5, the extreme damage losses,  $y$ , have been plotted against the number of acres of cropland,  $x$ , for the respective units. The enveloping curve,  $y = 12.6(3.5)^{10-n}$ , where  $n = \log_{10} x$ , has been drawn to fit the data. It should be noted that the enveloping curve is

applicable only for values of  $n$  between 4.0 and 7.2 and for conditions in Iowa where the hail damage is largely limited to field grain crops. The curve illustrates the necessity of applying hail insurance on the widest possible base. It has been noted that the effects of hail may be disastrous to the individual farmer. Even on the township basis, the possible losses within a quarter of a century are excessively large. Insurance companies, through their practices of reinsurance, are able to provide a wide base

TABLE 2.—Annual hail damage in Iowa for the nine crop-reporting districts

[Losses adjusted to the 1909-1914 price index]

District	Northwest	North-Central	Northeast	West-Central	Central	East-Central	Southwest	South-Central	Southeast	State
Year										
1923	\$86,522	\$328,012	\$167,319	\$273,929	\$344,206	\$170,661	\$429,967	\$99,632	\$1,078	\$1,901,326
1924	656,648	511,170	233,117	710,021	1,002,171	360,216	254,097	31,257	938,117	4,696,814
1925	441,330	385,807	423,111	624,688	485,708	445,823	926,398	79,295	1,141,543	4,953,703
1926	433,032	151,619	128,183	282,996	561,132	28,331	135,323	210,564	123,387	2,054,567
1927	557,728	355,055	619,930	320,748	605,665	728,572	141,265	82,382	312,743	3,724,088
1928	943,172	643,460	314,509	1,259,512	501,715	155,033	129,360	192,404	65,902	4,205,067
1929	1,148,422	60,173	364,744	644,044	121,381	36,487	21,205	6,576	173,176	2,576,208
1930	165,901	112,596	117,421	636,467	60,119	81,257	65,128	35,601	33,826	1,308,406
1931	127,130	338,719	373,392	138,673	204,315	336,672	166,068	45,783	59,170	1,789,922
1932	2,088,522	1,171,425	152,886	473,683	293,535	207,719	183,726	56,060	92,908	4,720,464
1933	2,246,666	213,350	1,468,515	1,290,376	158,805	428,964	37,145	694	59,362	5,903,877
1934	1,099,098	99,206	198,796	222,679	315,024	99,790	23,637	630	23,246	2,082,156
1935	219,291	42,513	76,697	120,498	19,473	127,773	130,994	4,354	2,254	743,847
1936	620,492	426,703	57,970	334,169	418,550	66,238	256,383	10,999	55,513	2,247,116
1937	147,814	125,164	41,535	385,442	109,857	14,184	74,837	213,435	61,797	1,174,065
1938	322,668	128,940	44,681	205,502	373,789	334,183	225,819	193,181	303,484	2,132,247
1939	521,030	38,583	144,465	317,029	114,863	21,104	332,299	18,812	9,366	1,517,551
1940	136,556	20,768	176,907	1,230,581	29,197	20,428	82,784	18,628	9,789	1,725,638
1941	137,670	444,995	113,101	517,519	285,831	596,012	239,915	63,866	49,628	2,448,537
1942	879,341	179,014	180,816	646,617	205,421	258,633	528,582	95,029	126,198	3,099,651
1943	2,639,723	287,176	132,757	1,766,838	1,604,240	51,801	638,930	124,489	547,604	7,693,558
1944	1,799,397	310,772	993,352	688,805	412,315	720,617	69,361	150,832	117,839	5,263,290
1945	262,756	497,795	818,975	818,291	439,798	863,518	196,659	322,597	69,953	3,575,342
1946	409,798	1,131,962	162,314	554,365	255,736	68,683	149,952	215,860	92,397	3,041,067
1947	1,459,667	460,895	16,738	469,530	50,655	118,807	298,097	79,601	26,587	2,980,577
1948	895,055	174,258	42,931	130,118	222,206	160,320	180,163	7,235	67,075	1,879,361

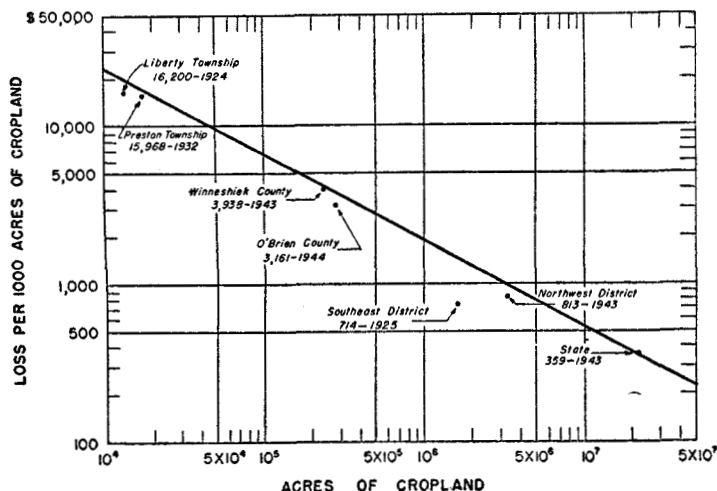


FIGURE 5.—Maximum annual hail damage,  $y$ , per 1,000 acres of cropland plotted against the number of acres of cropland,  $x$ , in the respective units (township, county, district, or State). Based on data for the period 1923-48 with damage adjusted to the 1909-14 price index. The heavy line is the enveloping curve,  $y = 12.6 (3.5)^{10-n}$ , where  $n = \log_{10} x$ .

for their operations, in many cases much larger than the base of the State of Iowa, which is the largest area considered in this study. It may be noted that the maximum risk for 1,000 acres of cropland in a township in Iowa is more than 45 times the maximum risk for 1,000 acres of cropland in the State of Iowa.

Table 2 shows the annual totals of hail damage for the period of record, for each of the crop-reporting districts, and for the State. The year of greatest damage in the State, 1943, had total losses more than 10 times the total losses for the year of the least damage, 1935. In terms of the 1909-14 dollar, there were 3 years in the 26-year period when the total damage for the State exceeded 5 million dollars; 7 years when it exceeded 4 million dollars; and 11 years when it exceeded 3 million dollars. If the data are desired in terms of 1950 dollars, then each loss shown in the table should be multiplied by 2.35. Some additional statistics for each crop-reporting district are given in table 3.

TABLE 3.—Standard deviation and standard error of average annual hail damage per 1,000 acres cropland in Iowa for the period 1923-48

District	$\bar{x}$	$s$	$\sigma$	$100 \frac{\sigma}{\bar{x}}$
Northwest	242	222	44	18
North-Central	122	108	21	17
Northeast	115	141	28	24
West-Central	187	133	26	14
Central	114	105	21	18
East-Central	117	115	23	20
Southwest	127	116	23	18
South-Central	62	59	12	19
Southeast	110	177	35	32
State	143	80	16	11

$\bar{x}$ , annual hail damage per 1,000 acres.

$\bar{x}$ , average.

$s$ , standard deviation,  $\sqrt{\frac{\sum (\bar{x} - x)^2}{n-1}}$ .

$\sigma$ , standard error  $\frac{s}{\sqrt{n}}$ .

$100 \frac{\sigma}{\bar{x}}$ , standard error expressed as a percentage of the average  $\bar{x}$ , number of values of  $x$ .

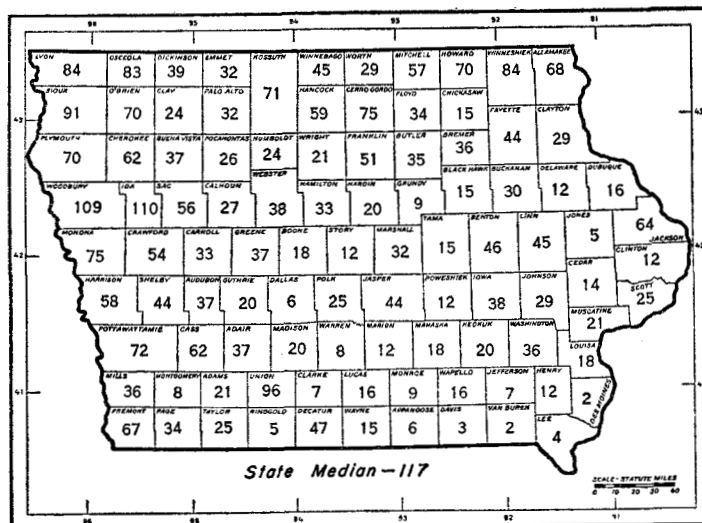


FIGURE 6.—Median annual hail damage per 1,000 acres cropland in Iowa. Based on data for the period 1923-48 with damage adjusted to the 1909-14 price index and to the 1944-48 crop production index.

#### ADJUSTMENT OF HAIL DATA TO LAND PRODUCTIVITY

It may be expected that hail damage would vary in the different sections of the State, in accordance with the productivity of the land. Thus, storms of similar intensity would not cause the same amount of dollar damage on land which would ordinarily produce 40 bushels of corn to the acre as compared to land which would produce 80 bushels of corn to the acre. Therefore, the adjusted hail damage, while reflecting the total damage in comparable terms, may not be wholly ascribed to meteorological causes.

The crop-production index, as given by the Iowa Department of Agriculture [9], varies from a low of 31 in Appanoose County to a high of 154 in Calhoun County (State average=100). In considering townships the range is more extreme; from a low of 19 in southern Appanoose County, to a high of 178 in southwestern Grundy County. The variation within each county is sometimes very great. Military Township in Winneshiek County, where severe hail damage occurred in 1943, has a crop production index of 92, as compared to an index of less than 50 in six other townships in that county, and a county crop production index of 63.

To ascertain the effect of the crop production index upon the hail damage data, the latter data for all counties and for the nine crop reporting districts were adjusted using the 1944-48 indices as published by the Iowa Department of Agriculture [9]. The resulting data are shown in table 4 and also in figure 6. As may have been expected, the range between the various sections of the State has been reduced. The greatest hail damage often, but not always, occurred in districts having a high crop production index. The distribution in figure 6 more closely resembles the hail frequency data. The maximum damage thus adjusted occurs in west-central Iowa in Ida County, while the minimum damage occurs in southeastern Iowa.



TABLE 4.—Hail damage in Iowa, 1923-48

[Adjusted to the 1909-14 price index and to the 1944-48 Crop Production Index]

District	Total dam- age	For each 1,000 acres of cropland										
		Average annual loss	Median annual loss	Maximum and year	Frequency							
					0	1-50	51-100	101-200	201-500	501- 1, 000	1, 001- 2, 000	Over 2, 000
Northwest.....	\$15, 257, 811	181	124	\$607-1943	0	6	5	5	8	2	0	0
North-Central.....	7, 448, 473	106	95	372-1932	0	9	5	9	3	0	0	0
Northeast.....	9, 383, 739	158	95	873-1933	0	6	8	6	4	2	0	0
West-Central.....	12, 765, 393	159	130	484-1943	0	3	7	11	5	0	0	0
Central.....	7, 247, 517	91	75	388-1943	0	8	9	7	2	0	0	0
East-Central.....	7, 399, 423	115	73	395-1945	0	10	6	5	5	0	0	0
Southwest.....	6, 725, 085	145	110	588-1925	0	6	6	9	4	1	0	0
South-Central.....	5, 053, 401	132	104	465-1945	0	9	4	6	7	0	0	0
Southeast.....	6, 005, 187	145	55	939-1925	0	11	7	3	3	2	0	0

## NOTES ON INDIVIDUAL HAILSTORMS IN IOWA

These notes have been selected, mainly from the Iowa climatological data and the Iowa weather reports, to show the conditions which attend some of the more severe hailstorms in Iowa. They are direct quotations from the original publications, and reflect the various styles and interests of the writers. References to dollar damage have been omitted, since the notes cover a period of more than 80 years with violent fluctuations in the value of the dollar.

June 30, 1863. "... After destroying all glass on the west side of the buildings, the wind veered around to the east, destroying also all glass on the north and east sides of most buildings in Monticello. The marks of the falling hail on the fences, buildings and trees were plainly visible for several years afterwards ... all crops and shrubbery was battered off close to the ground ... Upwards 500 lights of glass were smashed, and most of the families had to wait until Mr. Hickok sent to Dubuque for a new stock of glass ... M. M. Moulton, Monticello, Iowa.

May 17, 1877. "It commenced to hail at this station (Hamlin, Audubon County) in Hamilton township about 5 P. M. The wind had increased to nearly a storm; clouds very low and dark; hailstones measuring six inches in circumference, and falling to the ground in great force, smashing window panes, barking the apple trees, killing rabbits, birds, chickens, etc." D. C. Lewis.

June 25, 1877. "The hailstones were large—from the size of black walnuts down. They fell in vast quantities and with great force. In one place, where there was a ravine with steep slopes on each side, they were washed down into the ravine, filling it to a depth of five feet, and they were so well preserved by the rubbish washed on to them, that some were seen a week from the time they fell, although some of the hottest days of summer intervened." C. E. Tebbetts, Muscatine, Iowa.

April 21, 1878 (Easter Sunday). "Hailstones very large, measuring from five to ten inches around; some I saw measured were twelve and one thirteen inches around and four inches in diameter." Sac City.

"Immense hailstones fell in the track of the tornado, and at some distance on either side; some of these hailstones measured fourteen inches in circumference." Grant City.

"Hailstones, the size of a walnut, fell in sufficient quantity and force to break nearly all the glass on the western side of houses." Smithland.

"Very severe hailstorm, accompanied by rain, thunder and lightning; 6:30 to 7 p. m. Hailstones two and one-fourth to three inches in diameter fell ... Most of the stones were in the shape of flat discs; some were elongated spheres, and others nearly

round ... Hail drifted two feet deep in one place." Nashua.

"... Where hail stripped the trees as bare as in winter, utterly ruining all fruit and breaking thousands of panes of glass ... Cambridge Chronicle.

August 6, 1890. "... a very disastrous storm passed over the central part of Adair County and on south into Union County ... Mr. R. S. Williams says in a letter to me: 'The hail destroyed all green vegetation and small animals, such as rabbits, ground squirrels, etc., and all the birds. It fell to a depth of four inches, varying in size from a quail's egg to a hen's egg, and drifting in many places to a depth of six feet, where it remained, when protected by trash, for twenty-six days after the storm, or until September 1st.' The writer was past Mr. Williams' farm seven days after the storm, and took from a pile of several wagon loads, enough hailstones to freeze a gallon of ice cream. It is hard to realize what desolation this storm left in its track. In one field of corn of forty acres, there was not a sound ear to be found." Henry C. Wallace, Orient, Iowa.

"Hail commenced to fall at 7 o'clock in the evening of August 6th and continued for forty minutes ... On the bottomlands hail was drifted from four to six feet deep, and where protected by long grass, was found in large quantities twelve days after the date of the storm. The corn crop was almost entirely destroyed ... No livestock was killed, except a few pigs." Hugh McCornack, Creston, Iowa.

September 1, 1897. "Imagine, if you can, a tract of country at least sixty miles long and averaging two or three miles wide in which scarcely a stalk of corn is left standing ... Imagine, if you can, a strip three to four miles wide on each side of this first strip in which on the average, half the corn crop has been destroyed; put on top of this the wreckage of hundreds of windmills, the destruction of all the glass in the north windows of hundreds of houses, the loss of thousands of chickens and turkeys, the wreckage of orchards, vineyards and gardens, the damage to barns, sheds, cribs, etc., ... At least 40,000 acres of corn have been totally destroyed, while 70,000 acres have been so pounded and wrecked by hail that half or more of the crop is a total loss. ... At the Foster Farm ... the stubs of the stalks stand, on an average, about two or two and one-half feet high, but the balance of the stalks, ears, blades, etc., have been pounded off and are rotting on the ground.

"At W. R. Jeffrey's farm, in Highland township, the storm ... wrecked his fine new barn ... Howard Jeffrey ... was struck in the forehead with a hailstone and knocked senseless ... the north wall ... was blown in bodily ... This wall was two feet thick, seven and one-half feet high, fifty-two feet long, and only three or four feet of it above ground." Washington County local paper.

March 24, 1901. "... hailstones containing a large percent of mineral. Many persons in Sac City noted the peculiar softness of the large stones as they fell and some who attempted to taste them found them alkaline ... contained carbon, sodium, boron, and a little calcium ... Mr. A. L. Bownell, voluntary observer at Sac

City writes . . . "The hail was soft like snow, composed of pellets about the size of peas pressed together without breaking their shape . . . One (chunk) that I saw weighed fifty-seven ounces . . ." *Sac City Sun*

*June 20, 1908.* "A strip of country about fifteen miles wide, extending from Cresco, Howard County to McGregor, Clayton County suffered greatly from damage to crops, by wind, rain and hail. Cattle and hogs were killed by the hail or driven by the storm into the creeks and drowned . . . At a few places in the track of the storm the hail was of such size, and was driven with such force by the wind as to break siding on residences." H.A.F.

*August 1922.* "The first storm occurred on the 1st and affected portions of Dubuque, Jackson, Delaware, Linn and Jones Counties . . . Dubuque reported one of the most severe storms ever experienced but the greatest destruction to crops occurred in an irregular strip from one-half to four miles wide and forty miles long from the northwest corner of Delaware County southeastward. Hail drifted to a depth of six inches. . . . The most severe hailstorm occurred on the 9th and covered a large area in the west-central portion, but the greatest damage occurred in Crawford, Shelby, Audubon and Guthrie Counties. The principal damage was to corn but chickens and young pigs were reported killed by the score and two cows were killed . . . in portions of the area whole sections were hailed out so completely that not a single whole stalk of corn was left standing. In Guthrie County fields were white with hail and ditches two feet deep were completely filled. Four days after the storm there was sufficient hail in the ditches to make ice cream." F.L.D.

*July 1924.* "Hailstorms were very destructive, and the principal ones were embraced in a strip from Plymouth, Lyon, and Emmet counties southeastward to Delaware, Linn and Johnson counties . . . the heaviest damage occurred in Humboldt, Franklin, Hardin, Grundy, and Blackhawk counties. Reports were received from several counties of as many as three whole sections having crops completely ruined by hail and some stones were of enormous size. In Grundy County the hail drifted from a foot to 18 inches deep, and remained on the ground for 48 hours after the storm . . . Hundreds of chickens were killed, hogs and cattle were bruised and bleeding, and many roofs were punctured by hail." F.L.D.

*August 1925.* "What is believed to have been the worst hailstorm in the history of the State occurred on the 18th. The storm apparently developed in the southeast corner of Poweshiek County and moved southeastward over portions of Iowa, Keokuk, Washington, Jefferson, Henry, Des Moines and Lee counties . . . Some of the stones were reported of unbelievable size, some disc-shaped were four inches across and two inches thick. Many shingle roofs were pierced and stock of various kinds were killed. Passenger trains caught in the storm did not have a whole window glass left, and all windows on the exposed side of homes were broken. Fields of corn up to 75 acres did not have a single stalk standing. The damage to crops was so complete that many tenant farmers abandoned their leases and sought other employment." F. L. D.

*September 21, 1931.* "A severe hailstorm accompanied the tornado . . . in Bloomfield. The large hailstones, some more than 2½ inches in diameter, driven by the wind, broke more than 15,000 glass windowpanes. Nearly every roof along the path needed repair, and at least 600 homes must be reroofed. The hail damage was confined mostly to trees, windows, roofs, highlines and telephone wires."

*July 6, 1932 (3d of a series of damaging hailstorms on this date).* "In Iowa the storm was most destructive in and near LeMars . . . Nearly every building in LeMars suffered damage to windows and roofs, and the tops of several hundred automobiles were riddled. A number of pigs and livestock, hundreds of chickens, ducks and geese, and literally thousands of pheasants and other wild birds were killed."

*July 31, 1943, near Boone, Iowa.* "In the city of Boone there was considerable damage to electric signs, windows and roofs. Two greenhouses lost 2,300 panes of glass. Some automobile tops and some roofs were damaged in the southeast part of town. Crops were badly damaged or totally destroyed on about 200 farms, or on about 8,000 acres of land. Previous to the storm there were prospects of bumper yields of corn, soybeans and hemp, but after the hail some fields contained only short stumps of broken cornstalks. . . ." S. E. D.

## ACKNOWLEDGMENTS

The collection of hail damage statistics through the facilities of the Annual Farm Census originated with the late Charles D. Reed; many of the original data used in this report were compiled by Mr. Reed in a very convenient form. The reduction of the data to a standard price index was accomplished by Mr. Wayne L. Decker, and many of the same data were used by him in his study on hail frequencies. Assistance in statistical interpretations was given by Mr. M. D. Magnuson, and assistance in typing and the preparation of tables, charts, and figures by Miss Patricia Richtsmeier and Mrs. M. C. Blaess.

## REFERENCES

1. A. L. Shands (sections on hail distribution), *Hydro-meteorological Report No. 5*, U. S. Weather Bureau, Washington, 1945.
2. S. D. Flora, *Climate of Kansas*, Topeka, Kans., 1948.
3. Charles D. Reed, "Hail Damage in Iowa," *Monthly Weather Review*, vol. 59, No. 6, June 1931, p. 229 and vol. 56, No. 5, May 1928, p. 189.
4. Richard S. Roth, "Crop-Hail Insurance in the United States," *Bulletin of the American Meteorological Society*, vol. 30, No. 2, February 1949, pp. 56-58.
5. Charles D. Reed, "Twenty Years of Hail Damage in Iowa," *Iowa Climatological Data*, Des Moines, Iowa, July 1943.
6. Wayne L. Decker, "Hail-Damage Frequency," *Transactions of the American Geophysical Union*, vol. 33, No. 2, Apr. 1952, pp. 204-210.
7. Iowa Department of Agriculture in cooperation with the U. S. Bureau of Agricultural Economics, *Iowa Farm Prices and Indexes*, 1945, Des Moines, Iowa.
8. Iowa Department of Agriculture in cooperation with the U. S. Bureau of Agricultural Economics, *A Graphic Summary of Iowa Land Utilization*, 1949, Des Moines, Iowa.
9. Iowa Department of Agriculture in cooperation with the U. S. Bureau of Agricultural Economics, *A Graphic Summary of Iowa Land Productivity*, 1950, Des Moines, Iowa.